An Extended Approach Pertaining to the Energy Prediction of HVAC Plant using Machine Learning Techniques

A

SYNOPSIS

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IN

MACHINE LEARNING

By

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2K17-PFE-005

UNDER THE GUIDANCE OF

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DEPARTMENT OF COMPUTER SCIENCE
AND TECHNOLOGY

MANAV RACHNA UNIVERSITY
Established, vide Haryana Act no.26 of 2014
(Formerly Manav Rachna College of Engineering,
NAAC Accredited 'A' Grade Institute)

Year 2018

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DECLARATION BY THE SCHOLAR

I declare that the Synopsis entitled **"An Extended Approach Pertaining to the Energy Prediction of HVAC Plant using Machine Learning Techniques**" is prepared under the supervision of **Dr. Mrinal Pandey** submitted for the approval of Departmental Research Committee (DRC).

Signature of Supervisor

Signature of Scholar

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An Extended Approach Pertaining to the Energy Prediction of HVAC Plant using Machine Learning Techniques

Comprehensive Rationale of Present Research Work:

The world is facing a critical issue of over consumption of energy and its wastage. Most of the energy is consumed by Buildings. Several researchers have worked in this area as to how the problem of energy wastage should be handled. Researchers have tried to explore different aspects of energy wastage in buildings- Occupancy, Occupant behaviour, lack of robust methods for energy prediction and analysis, lack of Building management systems etc. Machine Learning has tremendous power which can be used to find solutions to various real life problems prevalent in the society. The researchers have made good use of machine learning techniques to develop solution models for combating energy wastage in buildings. Variety of available techniques in Machine Learning like Clustering, Association, Classification, Regression, Prediction and different algorithms in each have been applied on the energy consumption data collected from commercial buildings to analyse various aspects of energy usage like the manner in which energy is utilized in the buildings, distribution of energy among different components within buildings, detect the misuse of energy, predict the energy that is likely to be consumed by the building in the days to come by studying the previous energy consumption patterns, checking the effectiveness and robustness of Building Automation Systems if present in buildings and accordingly find solutions to minimize the faults in various aspects with the objective of conserving and optimizing energy.

Introduction :

One of the biggest issue of concern in the present scenario is the fast paced consumption of energy. Energy is very precious as it is produced by burning non renewable resources which take millions of years to generate. The technology advancements in the modern world may have made our lives easier but it certainly is taking toll on the consumption of energy. Almost everything requires energy to operate resulting in wiping off the precious resources quickly. With ever increasing modernization the depletion of energy resources is also increasing at an faster pace. So it is an urgent demand of nature to make efforts to fix this global issue.

Energy

Energy is the capacity of doing work. Energy is of many forms like kinetic, potential, thermal, electrical, nuclear, chemical etc., my focus being on electrical energy. In the modern world everything is automated. Most of the work is done by machines in every field. So energy is required for the working and smooth functioning of various types of machines, like microwaves, refrigerators, water heaters, washing machines and other appliances in homes and hotels, computers, printers in offices, heavy machines like machines required for welding, packaging, robotics in industries, energy required in means of transport.

Definition of Energy optimization

Energy optimization is defined as the measures adopted to use the energy in a more effective manner such that energy is saved and comfort is not compromised. Using the energy efficiently can assure betterment of quality of surrounding environment, protection of the nation, finance related security of people and increase in savings.

Need of Energy optimization

As told, if every field requires energy for work, a huge amount of energy is being consumed and that too at a fast pace. So there arises an urgent need that energy should be saved as far as possible. Major reasons for conserving energy are as follows:

- Save non-renewable energy resources from depletion: Non-renewable resources of energy are the fossil fuels like oil, coal and natural gas which take millions and millions of years to form. Conventionally these resources are consumed to produce energy. These fuels are used to run turbines which generate electricity. If the consumption of these fuels continue on a fast pace, then soon they will be depleted. So an alarming situation has arisen to save energy.
- Reduce carbon footprint: All the fossil fuels when burnt release carbon. More the fossil fuels burnt, more carbon is emitted. A high percentage of energy in the world is produced by using fossil fuels, which means carbon emission is high and consequently it causes various types of pollution in the environment like air pollution, water pollution. So if we put efforts to save energy, it will lead to less burning of fossil fuels and ultimately less carbon emission, thus helping in protecting our environment.
- Make energy available for future generations: If we save energy, we can avoid the early depletion of non-renewable resources which are primarily used to produce energy, hence ensuring the availability of energy for the generations to come.
- Reduce the cost of living: It is very obvious that if we consume less energy then electricity bills will reduce leading to more monetary savings.
- Increase life & decrease service cost of equipments: Regular and continuous working of machines causes wear and tear of their different parts. This requires frequent maintenance of the machines or replacement, both incur expenses. Replacement of expensive machines may require huge investments which may disturb budgetary planning.

Measures to save energy

After understanding the huge need to conserve energy, we should think upon the measures which should be adopted for energy conservation. A basic way to save energy and power in buildings(whether commercial or residential) is to do energy audit or energy inspection. An energy audit is done in a building for inspection and analysis of energy usage. The results of such inspection can be of much use for designing appropriate systems for conserving energy. Few other tips to save energy are:

- Put off bulbs, tubelights and other electrical appliances when they are unused.
- Maintain indoor temperatures in buildings by keeping windows, window shades and blinds open or close as required.
- Change normal light bulbs with CFLs and LED lights.
- Keep changing air conditioner, furnace and heat pump filters at regular intervals.
- High efficiency and solar heating systems should be installed in place of old conventional water heaters.

Energy optimization in Buildings

Since I have explained the need to conserve energy and the measures of doing so, we should identify the areas where maximum energy is consumed. It will give us a direction in which we should apply efforts to conserve energy so that a huge amount of energy is saved and we are able to contribute to the welfare of mankind and society.
There are three broad categories which consume energy : Buildings, Industry and Transportation. Studies show that throughout the world, buildings are accountable for 40% of energy consumption, followed by Industry and Transportation which consume 32% and 28% of energy respectively.
Buildings may be Residential like houses and apartments, or Commercial like offices, hotels, hospitals etc. In each type of building, energy is consumed to a large extent.

There are various dimensions which account for energy consumption in buildings:

- Occupancy: It is the quantity of people present in a building. If the building is heavily occupied then greater amount of energy will be required to maintain a certain temperature within the building whereas if the building is less occupied then less energy will be required to maintain the ambient temperature.
- Occupant Behaviour: The behaviour of occupants in a building also impacts the amount of energy consumed. Every individual has his/her own preferences regarding the inside environment of a building in which he/she is comfortable. Some people like natural sunlight and fresh air so they tend to keep the windows and doors open which ultimately leads to less energy consumption, whereas some feel comfortable in artificial bright lights and air conditioned environments, so they keep lights, fans and air conditioners in switch on mode, thereby leading to large energy consumption. In addition to this, due to the careless behaviour some occupants tend to leave the electronic appliances in switch on mode even when the building is unoccupied. These acts result in wastage of energy.
- Change in ambient/weather conditions: The consumption of energy in a building is also affected by the outside temperature. This is so because when the outside temperature increases in hot summer months, the inside temperature of the building also increases which leads to more energy consumption to maintain the desired temperature in the building.
- Faulty equipments: The electronic appliances and equipments deployed in buildings may be poorly designed, low quality, very old or require maintenance. Such equipments tend to consume more energy than usual.
- Different energy requirement during non-peak hours: When the buildings are generally unoccupied or less occupied like office buildings during night time, the required energy

is less. At that time also if more energy is being consumed than expected, it indicates discrepancy somewhere.

- Huge amount of energy used by HVAC: The Heating, Ventilation and Air Conditioning unit consumes a large percentage of energy in a building. HVAC consists of several distinct components which operate individually and consume power. Collectively they are responsible to maintain the desired temperature in a building.

Review Of Literature:

Broadly there are three areas which consume most of the energy- Buildings, Transportation and Industry. According to the survey performed by ASHRAE i.e. "American Society of Heating, Refrigeration and Air conditioning Engineers", out of the three areas, buildings are accountable for nearly 40% of energy usage throughout the world and it is greater than the energy consumed by other two areas, industry and transport which as per reports comes out to be 32% and 28% respectively. If we concentrate on the energy usage within a building, nearly 40% of total energy is used by the HVAC (Heating, Ventilation and Air conditioning) system, 16% is used by lights, 10% is consumed by water heaters, lifts and electronics consume 9% of the energy and 25% is used by other appliances. Based on these reports we have reviewed the work of several authors related to conservation of energy within buildings.

(Tsanas, A., & Xifara, A.,2012) proposed a framework in which they selected 8 different characteristics of a residential building as input parameters and depicted their effect on the 2 output parameters- Heating load and Cooling load. Linear Regression and Random Forests were applied and results showed that Random Forests were better at predicting Heating and Cooling load in terms of accuracy.

(Khan, I. et. al.,2013) gave description of 3 techniques of data mining-Classification & Regression, Cluster Analysis and Outliers Detection in order to detect unusual lighting energy usage by the analysis of hourly recorded data of energy consumed and peak demand in an official building situated in Rome, Italy. The authors came up with the conclusion that Classification and Regression tree with Generalized Extreme Studentized Deviate outliers detection technique is very accurate. Clustering with K-Means algorithm identified some unusual consumption but it was less suitable for accurate detection of outliers. DBSCAN clustering algorithm could not identify artificially created faults but it managed to collect all the outliers in the same cluster.

(Chen, C.et. al.,2013) did analysis of the energy usage and faults in smart homes by applying machine learning techniques-Classification, Clustering and Outlier detection. A framework was developed that identifies correlation between home-based activities and power usage. The authors designed a web based system which could be run on a mobile phone or computer to alert users regarding the energy they consume individually so that they plan to perform activities such that energy is conserved.

(D'Oca, S., & Hong, T. ,2014) devised a model which combined the techniques of "Statistical Analysis" GLMs(generalized linear models) with those of Machine Learning -Clustering and ARM(Association Rule Mining). The model identified valid patterns of operating windows in sixteen offices situated in Frankfurt Germany. The results of study showed that people working in buildings with natural ventilation can accept a wider range of temperatures than those who work in air buildings.

(Xiao, F., & Fan, C.,2014) developed a framework using machine learning techniques of Clustering and Association for the analysis of big datasets in BAS (Building Automation System) aiming to improve the operational performance of building. The proposed method was deployed on the tallest commercial building of Hong Kong.

(Zhao, J.et. al.,2014) proposed a machine learning approach using Classification and Regression which used power consumption data of electric and electronic appliances in offices to reveal the building occupant's passive behaviour. Fifteen occupants in a medium sized official building of Pennsylvania in US took part in the study. In their study the authors pointed out that the impact of occupancy schedule on the HVAC energy usage of the building has huge differences for the buildings within different climate and atmosphere conditions.

(Fan, C.et. al.,2014) proposed a data mining based approach using Outlier detection, Clustering and Prediction for creating ensemble models for forecasting day ahead's energy consumption and peak power demand. Hong Kong's tallest building was used as case study for this purpose. Because of using ensemble learning models, better accuracy was achieved as it is more advantageous than single learning models.

(Chou, J. S., & Bui, D. K. ,2014) used Regression and Classification techniques of machine learning and ensemble models to forecast energy performance of building by predicting heating and cooling load with more efficiency and accuracy while in the design stage of building. This estimation can lead to greater comfort for the occupants of building, extended life of equipments, energy savings and lower maintenance cost.

(Jain, R. K. et. al.,2014) proposed a sensor-based model for forecasting the energy consumed by a multi-family residential building in New York City. The model was built using Support vector regression. Authors analysed the prediction performance through the perspective of time and space and found that most optimal prediction was hourly prediction at by floor levels.

(Braun, M. R. et. al.,2014) used Multiple Linear Regression technique for predicting the energy consumption in a supermarket. A supermarket located in the UK Yorkshire and Humber region was taken as case study. Energy and gas consumption data of 2012 was taken as the base data. Predictions were made for the periods from 1961 to 1990 and from 2030 to 2059. Results show that electricity consumption is estimated to increase by 2.1%. Also the temperature in 2040s is expected to remain almost same as in 2012 but humidity is expected to increase by 12%.

(D'Oca, S., & Hong, T.,2015) proposed a model using machine learning techniques-Classification and Clustering to identify patterns of occupancy in offices. To perform their study the authors took an office building situated in Frankfurt Germany. The study discovered occupancy related and archetypal user profile rules for which various energy saving strategies and recommendations related to building design might be suitable.

(Zeng, Y.et. al.,2015) proposed a data mining method using Prediction and Neural networks to reduce the energy used by HVAC by optimization of its 2 variables, the "supply air static pressure" and "supply air temperature" set points. They performed experiments which revealed that energy use can be lessened if only inside room temperature needs to be maintained but keeping humidity levels in control constrained the capabilities of energy savings in HVAC.

(Fan, C.et. al., 2015) developed a generic approach for discovering temporal(time related) knowledge for discovering large BAS(Building Automation System) data of Hong Kong's tallest building. The machine learning techniques used are Clustering, Ensemble learning and Temporal Association rule mining. The mined knowledge helps identify faults and anomalies in building operation, predicting building system's performance and energy saving.

(Zhou, H. et. al.,2015) proposed a strategy to control local areas making use of Computational Fluid Dynamics(CFD) simulation results. K-Means partitional clustering algorithm was used to group a single room into several zones on the basis of thermal comfort. Thermal comfort indices were retrieved using Predicted Means Vote model or Extreme Learning Machine. The HVAC can be controlled for each of the individually clustered zones in the room,thus aiding in energy conservation. The demonstration was done in a lab in a University in Singapore.

(Akkaya, K. et. al.,2015) surveyed the already existing work for monitoring the occupancy in buildings and various techniques for smart commercial buildings. The occupancy level in different zones of buildings can be monitored in different ways: Either using the existing wi-fi infrastructure which is less expensive but may compromise on accuracy. The other way is to deploy extra hardware and software like sensors, cameras, RFIDs and special apps on occupant's mobiles. These may incur more cost but is of course more accurate to detect occupancy. This information can be used to smartly control HVAC so that energy is conserved.

(Tardioli, G. et. al.,2015) in their research proved that Data driven models(also known as Black box approaches) are better at predicting and forecasting energy consumption in buildings as compared to Physics based models(White box based approaches). Various techniques of Data driven models like LR(Linear Regression), MLR(Multiple Linear Regression), ANN(Artificial Neural Networks), SVM(Support Vector Machines) and DT(Decision Trees) help in accurate prediction of energy use at urban level.

(Wei, X. et. al.,2015) applied several data mining algorithms(MLP, MLP Ensemble, Standard Regression CHAID, Exhaustive Regression CHAID, Boosting Regression Trees, Random Forest Regression, MARSplines for Regression, Support Vector Machine Regression) to calculate the energy consumption by various components of HVAC, keeping the Indoor Air

Quality in consideration. MLP ensemble model performed best. For minimization of energy consumption A Multiple Objective Particle Swarm Optimization algorithm was applied for optimization of supply air temperature and static pressure control settings. For experiment the data collection source taken is Energy Resource Station situated on the campus of the Des Moines Area Community College Ankey Iowa.

(Peña, M. et. al.,2016) have proposed a data mining based decision support system to tackle the energy efficiency and power consumption problem in smart buildings. The BlueNet building located in Spain is taken for case study. The devised method focuses to improve the EMS (Energy management System) installed in smart buildings that intelligently controls the activation of devices with the objective of minimizing power consumption.

(Park, H. S.et. al.,2016) in their work developed 6 energy benchmarks to improve the operational rating systems of official buildings making use of decision tree method. The proposed system is capable to be used to evaluate a building's energy performance on the basis of actual energy consumption. The developed system was evidently better when compared to baseline and conventional systems.

(Zhou, K.et. al.,2016) proposed a process model which makes use of Big data for smart energy management. The authors took smart grid as the background for their research and systematically reviewed Big data analytics for managing the energy smartly.

(Naganathan, H. et. al.,2016) developed a framework in which they used clustering algorithm and semi-supervised learning techniques to identify electricity losses during transmission i.e between source and destination. The technique also helps in optimizing the losses. Deep learning is used for semi-supervised machine learning because of its ability to learn both labelled and unlabelled data. The electricity consmption, heating , cooling and outside temperature data was obtained from a research university campus in Arizona.

(Marasco, D. E., & Kontokosta, C. E.,2016) developed a Machine Learning classifier (Falling Rule List classifier) to predict Energy Conservation Measures(ECM) eligibility. This prediction is done based on the availability of certain building characteristics. The prediction done by this classifier will reduce the need of energy audits which are time consuming and expensive.

(Jia, M. et. al.,2017) conducted a survey of occupant behavior , its modeling and simulation methodologies and technologies for energy efficiency in buildings. Comparison and analysis of these modeling methods is performed considering the pros and cons of each.

(Li, G.et. al.,2017) in their work proposed an approach using machine learning techniques-Clustering and ARM(Association Rule Mining) for identifying and interpreting the patterns of energy consumption and extracting rules for energy consumption in VRF i.e "Variable Refrigerant Flow" systems responsible for using a greater percentage of electric energy in buildings. These can be used for estimating energy conserving potential for compressors.

(Rubio-Herrero, J. et. al.,2017) used Deep Learning using RNN(Recurrent Neural Networks) for modeling the power consumption of building's HVAC and zone temperatures. An RNN architecture called LSTM (Long Short Term Memory) is used to devise the solution. This RNN resulted in much lower Mean square error as compared to other machine learning techniques like Linear Regression, Multilayer Perceptron, Linear Support Vector Regression and Random Forests.

(Fan, C. et. al.,2017) applied Deep learning for the prediction of cooling load profiles in an educational building in Hong Kong 24 hrs ahead of time. The deep learning model for prediction, Deep neural network was compared with typical prediction techniques including MLR(Multiple Linear Regression), EN (Elastic Nets), RF(Random Forests), Gradient boosting machines,SVR (Support Vector Regression), Extreme gradient boosting trees. Results showed that Deep Learning technique performed better in predicting the cooling load of the building. Also non linear prediction techniques performed far better than linear ones.

(Konis, K., & Annavaram, M.,2017) presented a prototype software named OMG(Occupant Mobile Gateway) developed for smartphones or server. Classification was applied to divide the occupants into different categories on the basis of whether they were comfortable with the indoor temperature or not. Logistic Regression was applied to create comfort models for occupants. Data was collected from four sites which consisted of academic, official and laboratory buildings in California. Basically the machine learning algorithms were applied to predict the temperature range for occupants according to their comfort.

(Yildiz, B. et. al.,2017) reviewed several machine learning models like Regression,ANN (Artificial Neural Networks), SVR (Support Vector Regression) which have been used to forecast the electricity load for buildings. They worked on the data collected from a University campus in New South Wales. They found that Regression models outperformed other models in predicting total building energy load and HVAC loads. And forecasting for single building is difficult as compared to forecasting loads for several buildings in a campus.

(Kiluk, S.,2017) made use of Nearest Neighbour Clustering and Classification Prediction techniques to evaluate and compare diagnostic information systems to supervise the efficiency of district heating supplied buildings. The energy consumption data on hourly basis was gathered from different types of buildings in Sweden.

(Araya, D. B. et. al.,2017) proposed two frameworks for anomaly detection in HVAC power consumption. One was a pattern based anomaly classifier called CCAD-SW(Collective contextual anomaly detection using sliding window) which created overlapping sliding windows so that anomalies can be pointed out as soon as possible. This framework made use of bagging for improved accuracy. Another was prediction based anomaly classifier called EAD(Ensemble Anomaly Detection) which used Support Vector Regression and Random Forests. Experiments were performed on HVAC power consumption data collected from a school in Canada and results show that EAD performed better than CCAD-SW in terms of

sensitivity and reducing False Positive rate.

(Ahmad, M. W. et. al.,2017) applied and compared two Machine Learning techniques with the objective of predicting the energy to be consumed in building. They applied Multi-layer feed-forward backpropagation ANN(Artificial Neural Network) and RF(Random Forests) taking various input parameters for predicting the energy consumed by HVAC in a Hotel building in Madrid, Spain. The authors concluded that ANN outperformed RF to some extent with low MAPE, RMSE , MAD, CV.

(Manjarres, D. et. al.,2017) proposed a framework(Next 24-h energy) using Random Forests to minimize the energy consumption by HVAC in an office building in Spain. The full HVAC mode operates on regular values according to the season and day of the week. But the proposed framework made use of weather forecast data and accordingly switched the HVAC in MV(Mechanical Ventilation) mode in which outside fresh air was circulated in the AHU for cooling to some extent while the heating and cooling coils were inactive. This resulted in good amount of energy conservation(48% and 39% for heating and cooling respectively).

(Rahman, I. et. al.,2018) used various supervised classifiers- DT(Decision Trees), DA(Discriminant Analysis), SVM (Support Vector Machines) and KNN (K- Nearest Neighbors) to disaggregate the data of power consumption by multiple HVAC units into that consumed by individual HVAC, while the data was retrieved collectively from single meter to reduce cost and complexity. Power consumption information of individual appliances is necessary for accurate energy consumption monitoring. The experiment was performed by collecting data from a commercial building in Alexandria. The results show that K- nearest neighbour was most efficient in power disaggregation.

(Carreira, P. et. al.,2018) proposed a system which receives occupant preferences of comfortable temperature, and based on these inputs manages the HVAC automatically to vary the room temperature(increase/decrease). Results of the study indicate that using k-means machine learning technique, HVAC system can be automated to reduce energy consumption while maintaining desired comfortable temperature.

(Gallagher, C. V. et. al.,2018) investigated the use of several machine learning algorithms like Regression, K-nearest neighbours(KNN), Artificial Neural Networks(ANN), Support Vector Machines(SVM) for measurement and verification of energy conserved in Industrial buildings. For testing the proposed approach, a biomedical manufacturing industry was taken. Authors have proved that machine learning is capable of reducing uncertainty in the process of measurement and validation.
(Deb, C. et. al.,2018) applied MLR(Multiple Linear Regression) and ANN(Artificial Neural Network) to predict the most important factors or variables which help in energy savings. The energy audit data of 56 buildings in Singapore was taken for experiment. All the possible combinations of 14 important variables were tested using machine learning techniques and those variables which resulted in the models with best prediction accuracy were selected. Results show that ANN is better than MLP in terms of accurately predicting the energy savings.

(Peng, Y. et. al.,2018) proposed a demand driven strategy using k-means and k nearest neighbours algorithms for cooling control of several rooms including single person rooms, multi person rooms and meeting room in an office building of Singapore. The motion sensors installed in the rooms were used to gather occupancy data and the system was learned using machine learning algorithms for predicting the room occupancy according to time of the day and accordingly switching the HVAC temperature between comfort mode and setback mode. The cooling was gradually reduced in rooms which were predicted to remain vacant after a particular time, thus minimizing energy wastage. An average of 21% energy saving was reported.

(Cho, J. et. al.,2018) used Decision Tree Analysis to predict the cost estimations of HVAC while designing buildings. The HVAC sub systems are CP(Central Plant) system, WD (Water Side Distribution) system and AC (Air Conditioning) system. Different combinations of these sub systems result in different costs of HVAC plants. The study was carried out in office buildings in Korea. The study showed that AC component of HVAC has maximum impact on the cost followed by CP and then WD has minimum impact.

Problem Statement

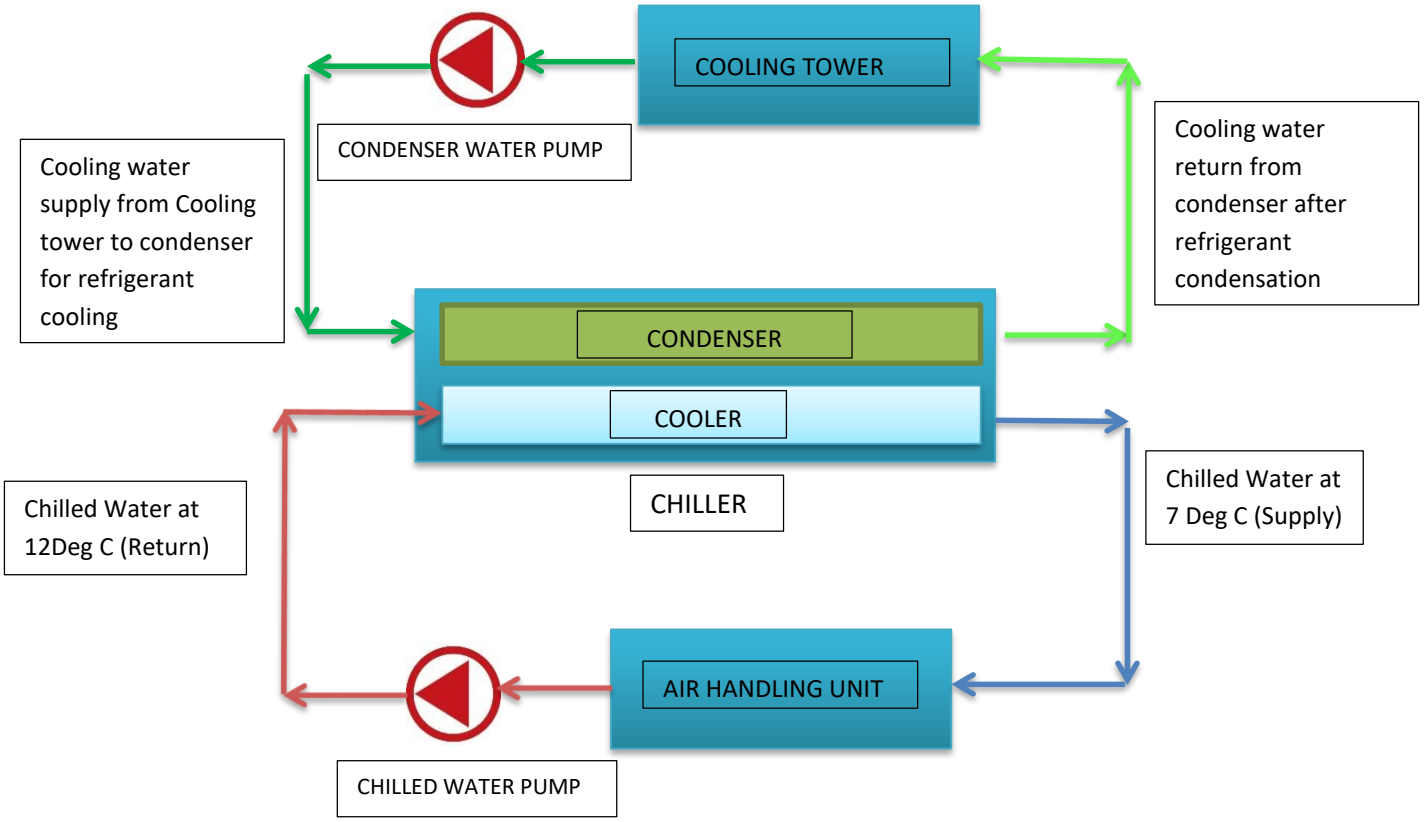
The consumption of energy in enormous amounts is one of the prime areas of concern for the researchers globally. The focus is on buildings as they are the biggest consumers of energy. The analysis of energy consumption pattern of buildings diverts our attention towards the Heating, Ventilation and Air Conditioning system which accounts for maximum energy consumption within buildings. This research will propose ML based extended intelligence approach to analyse the HVAC data obtained from various sensors for commercial buildings and to predict abnormal energy consumption due to HVAC plants within a building and can help to identify the cause of wastage of energy and can save the energy.

Motivation

As is evident from the review of literature, maximum percentage of energy in a building is consumed by Heating, Ventilation and Air Conditioning(HVAC) unit. So we will concentrate our attention on HVAC aiming to conserve energy. An HVAC unit consists of distinct components like Chillers, Cooling towers, Primary pumps, Secondary pumps. Each of these components perform their designated work and consume power to operate. In a conventional HVAC plant room all these components work independently without any synchronization. If we are able to establish synchronization between these components both for building full load requirement and part load requirements, then energy can be saved to much larger extent. Building's full load requirement means the total amount of energy that the building will consume when it is fully occupied, and part load requirement means the energy required when the building is partially occupied. Buildings must be capable of effectively handling maximum energy load without any failure, so HVAC equipments are designed to work most efficiently under full load conditions. In real scenarios, a building is generally not fully occupied, so

HVAC should operate efficiently for part load requirements also. Sometimes HVAC components cannot work efficiently under part load conditions. This is a limitation to be considered.

Major components of HVAC


COOLING TOWER
CONDENSER WATER PUMP
Cooling water supply from Cooling tower to condenser for refrigerant cooling
Cooling water return from condenser after refrigerant condensation
CONDENSER
COOLER
CHILLER
Chilled Water at 12Deg C (Return)
Chilled Water at 7 Deg C (Supply)
AIR HANDLING UNIT
CHILLED WATER PUMP

Chiller: Chiller is a very important component of HVAC unit. It consists of Compressor, Condenser, Cooler, Expansion device. Its function is to generate chilled water at the required temperature (5 to 10 deg C).

Cooling Tower: It is the most common and efficient device for cooling condenser water. Such cooling is required to continue the cycle of cooling.

Condenser Water Pumps: Condenser water pumps are employed to circulate water between cooling tower and condenser in any HVAC system.

Primary and Secondary Pumps: The pumps are are used to circulated return chilled water from building to Chiller and secondary pumps are used to circulate water from chiller to building as per building load requirement.

Air Handling Unit: It is used to carry the air to supply air ducts and then distributed equitably throughout the space. AHU consists of a coil bundle in the AHU where the chilled water is circulated and heat exchange happens between water and air.

Working of the System:

The central chilled water air-conditioning system is applicable for bigger buildings where the complete air conditioning system is placed at one location. These kind of systems are more efficient than standalone units and are easy to maintain.

The main components of this kind of system are Chiller, Primary Pump, Secondary Pump, Condenser water pump, Cooling Tower and Air Handling units.

The Chiller is heart for any air conditioning system which consists of Compressor, Condenser, Cooler and Expansion device. There is a refrigerant used in the chiller which by its properties when expanded from higher pressure to lower pressure it produces cooling Effect. The refrigerant is first compressed in the compressor to increase the pressure of the refrigerant. As per thermodynamic laws that whenever we increase the pressure of any gas the temperature also increases. Now the next step is to reduce the temperature of the refrigerant and liquefy the refrigerant in the condenser.

Condenser generally is a shell and tube type heat exchanger in which on shell side is the refrigerant and tube side is condenser water coming from cooling tower. The high temperature refrigerant in converted to lower temperature liquid refrigerant. This heat exchange is done by the water coming from cooling tower at 32.2 Deg C and after doing the heat exchange goes back to cooling tower at 36.4 Deg C. The circulation of water is done by condenser water pumps. So the purpose of cooling tower is to reduce the temperature of water by rejection of heat to the atmosphere.

The refrigerant is then allowed to expand through expansion valve is which there is a sudden drop pressure and as refrigerant has its properties that when a refrigerant is suddenly expanded from higher pressure to lower it cools down from an approximate temperature of +40 Deg C to +4 Deg C.

The expanded and cold refrigerant enters in the shell and tube cooler/ evaporator in which the cold refrigerant does the heat exchange with chilled water. The chilled water circuit in india generally operated at 6.7 Deg C/ 12.2 Deg C.

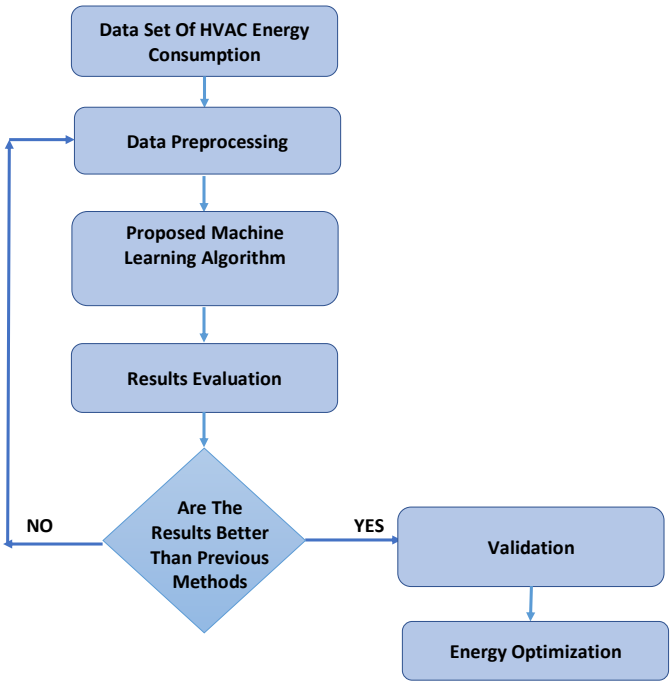
This chilled water at 6.7 Deg C is circulated to Air handling unit through primary and secondary chilled water pumps. Air handling Units(AHU) are equipment with cooling coils and fans arrangements which is primarily used to give cold air to the rooms with the help of chilled

water being circulated. The hot air is sucked through the ducts and passed over the chilled water coil and therefore heat exchange takes place between air and water.

Research Objectives

- To perform a thorough literature review to identify the suitable Machine Learning algorithms available for problem solving.
- To design and perform a number of experiments that can facilitate to evaluate the performance of the ML techniques for the Energy prediction of HVAC plants.
    - ➢ To identify the correlation among the attributes of HVAC energy consumption data.
    - ➢ To apply feature selection on HVAC parameters.
- To propose an efficient and more accurate Machine Learning based approach for the prediction of energy consumption (HVAC) in commercial buildings.
- To analyse and compare performance of the proposed approach on established evaluation criteria (metrics) and on standard benchmark dataset for the validation of the prediction of energy consumption in HVAC plants.

Methodology



With the objective of optimizing energy in HVAC plants, the methodology adopted will be as follows:

- Obtain the energy consumption data of an HVAC plant.
- Pre-process the data to remove any outliers and extra redundant parameters not relevant to the research work. Identify and select the suitable features for the task.
- Develop suitable machine learning algorithm and apply them on the pre-processed dataset.
- Interpret and evaluate the results obtained.
- If the obtained results are better than the previous methods i.e. if the energy and other resources are saved to greater extent than we have achieved our objective.
- Validate the results by applying the algorithms on variety of test data. If the results come out to be better in each case then it is evident that energy has been optimized.

Work Plan

Research Activities	Jan 17- June 17	July 17- Dec 17	Jan 18- June 18	July 18- Dec 18	Jan 19- June 19	July 19- Dec 19
Course Work						
Define Research Problem						
Literature survey						
Identification of suitable machine learning algorithm						
Implementation						
Results interpretation & Validation						
Thesis Writing						

Expected Outcome:

- An extended approach will be developed to predict abnormal energy consumption due to HVAC plants for commercial buildings.

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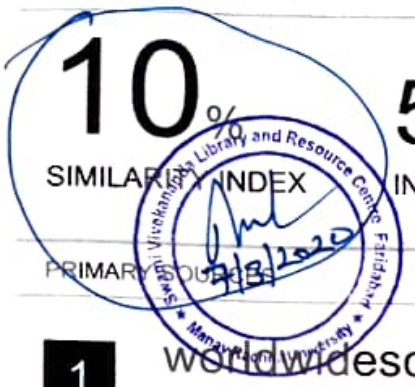

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